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WOOD PAVING IN THE UNITED STATES.

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WOOD PAVING IN THE UNITED STATES.

INTRODUCTION.

For more than seventy years wood has been used for street paving. In the beginning, however, incomplete knowledge and wrong methods led to failure, and it is only within the last ten years, or since the introduction of the present creosoted longleaf pine block, that wooden pavements have been laid with greater success. Wood has many qualities which especially adapt it for paving, and, with a better knowledge of the fitness of woods other than those now used, and of the effect of preservatives upon durability, it is almost certain that its use for this purpose will steadily increase.

Until the beginning of the study made by the Forest Service, longleaf pine was practically the only wood used for creosoted block pavements in the United States. The only important exception is in the city of Minneapolis, where Norway pine and tamarack were laid six years ago and have proved successful. Longleaf pine has advanced in price so rapidly as to make its use for paving very costly. Since the United States has a large variety of commercial woods, it seemed that there ought to be some cheaper and more abundant than longleaf pine, which would prove suitable for pavements. The Forest Service accordingly undertook a study of the subject.

In the course of the study, the Forest Service gathered data upon creosoted block pavements in nearly every city in the United States which had laid them, and at those creosoting plants which treat wood paving blocks. The data thus obtained, together with the conclusions drawn from them and a description of the experimental pavement laid in the city of Minneapolis, are given in this circular.

PROGRESS OF WOOD PAVING.

The first use of wood for paving is said to have been in Russia, where rude blocks were laid several centuries ago. Wood was introduced into New York City in 1835–36, and into London in 1839. Continental Europe was slower to take it up.

During the first thirty years of wood paving in England and America the chief consideration seems to have been the form of block.

The large and unequal interstices between the round blocks then commonly used permitted the edges to wear off rapidly into a corduroy condition which was uncomfortable to the traveler, and which hindered both drainage and cleaning, thus making the pavement insanitary and hastening its decay. To remedy this, other forms of block were devised, many of which were patented.

In the United States perhaps the most conspicuous of these blocks was the "Nicholson," patented in 1848 and laid extensively in the ten years following the civil war. The block was rectangular, which gave equal interstices; but this by no means solved the problem, and results were no better than before. Little thought was given to the kind of wood used, and as soft a wood as white pine was frequently laid. The blocks were neither seasoned nor treated with chemical preservatives, and quickly decayed. Wide joints permitted water to get under the pavement, where it was absorbed by the blocks, with the result that they swelled, so that the pavement often heaved from its foundation. Finally, the foundation was usually of untreated planks, laid directly upon earth, so that they soon decayed, while the pavement sank into ruts and holes.

Round blocks, mostly of cedar, were extensively laid in the Middle West. They made neither a durable pavement nor in any way a satisfactory one. But they were cheap and served a good purpose in tiding fast-growing cities over a critical period. There have also been laid in various cities pavements of oak, cypress, white pine, hemlock, Washington red cedar, cottonwood, mesquite, Osage orange, redwood, Douglas fir, and tamarack. In nearly all these cases the blocks were untreated, or at most dipped or boiled for a short time in tar, asphalt, or other mixture of supposed preservative value, and they failed to give satisfactory results. Untreated American red gum was tried in England, and for a time raised great hopes, but it finally proved unsatisfactory.

Some species of eucalyptus, especially karri (*Eucalyptus diversicolor*) and jarrah (*E. marginata*), which are very dense, hard, Australian woods, have been laid extensively in England. In London these woods have shown a life of from fifteen to twenty years, but continued use has not entirely justified the hopes first entertained for them. Their structure is too dense to permit impregnation with chemical antiseptics, without which they absorb water and swell. They wear much more slippery than most native woods, and they are not immune from decay, though because of certain antiseptic gum-resins which they contain they are more so than any untreated native woods. In England, however, they are still used. Jarrah blocks were laid on Twentieth street, New York City, in 1895, but were removed in 1904. The cost of this pavement was about $5 per square

yard, which would exclude these woods from extensive use in America even should they make a better pavement than our best creosoted native woods, which is not likely.

After the failure of untreated native woods, attention was turned to wood preservatives. For the treatment of wood paving, the tendency has been to narrow down (for reasons discussed on page 13) to the use of one material, the dead oil of coal-tar, commonly called creosote, either pure or in mixture with resin, pitch, or other materials. Creosoted southern pine paving blocks are said to have been laid in the United States at Galveston, Tex., as early as 1873. This pavement, in spite of being laid on a foundation of sand, gave satisfactory service for nearly thirty years, and was destroyed only by the great flood of 1900. But this good beginning was not at once followed up, and only within the last ten years has the matter received systematic attention in this country.

There were in service in the United States on December 31, 1905, about 1,400,000 square yards of creosoted wooden block pavement. The five cities having the largest amounts at that date were:

	Square yards.
Indianapolis, Ind	404, 800
New York, N. Y	[a]178, 264
Minneapolis, Minn	[b]148, 465
Toledo, Ohio	131, 451
Boston, Mass	47, 500

QUALITIES OF CREOSOTED WOOD PAVEMENT.

The success of the modern wood block pavement is due to several things. The wood is carefully selected, both as to kind and quality; it is cut accurately into rectangular blocks, is put through seasoning processes (but see page 13), and is preserved from decay, with creosote. Enough of this oil is injected to reduce to a minimum the absorption of water and consequent expansion and contraction of the pavement. The blocks are then laid with the grain vertical, over an accurately surfaced cushion on a solid foundation of cement-concrete. They are close jointed, and, in the best practice, the joints are made waterproof. The result is a pavement which is smooth, quiet, resilient, sanitary, easily cleaned, and easily repaired. It wears evenly, and lasts longer than one of untreated woods.

Opinions were sought from engineers of a number of American cities who have had experience with the modern creosoted block pavement as to the comparative qualities of different kinds of pavement. The inquiry was made in a form slightly modified from the one pre-

[a] About 100,000 square yards additional laid during 1906.

[b] About 50,000 square yards additional laid during 1906.

sented by Mr. George W. Tillson, chief engineer to the bureau of highways, borough of Brooklyn, New York City, in his text-book on "Street Paving and Paving Materials." The results of this inquiry are given in Table 1. Under the percentage column the various qualities desired in a pavement are assigned proportionate values, the total being 100 points. The pavement ranking first under any given quality is given the full quality percentage, the rest grading down from this value in proper proportion. The figures given are the averages of ten replies to the inquiry.

TABLE 1.—*Comparative value of different pavements.*

Pavement qualities.	Percentage.	Granite.	Sandstone.	Asphalt (sheet).	Asphalt (block)	Brick.	Macadam.	Creosoted wood.
Cheapness (first cost)	14	4.0	4.0	6.5	6.5	7.0	14.0	4.5
Durability	20	20.0	17.5	10.0	14.0	12.5	6.0	14.0
Ease of maintenance	10	9.5	10.0	7.5	8.0	8.5	4.5	9.5
Ease of cleaning	14	10.0	11.0	14.0	14.0	12.5	6.0	14.0
Low traction resistance	14	8.5	9.5	14.0	13.5	12.5	8.0	14.0
Freedom from slipperiness (average of conditions)	7	5.5	7.0	3.5	4.5	5.5	6.5	4.0
Favorableness to travel	4	2.5	3.5	4.0	3.5	3.0	3.0	3.5
Acceptability	4	2.0	2.5	3.5	3.5	2.5	2.5	4.0
Sanitary quality	13	9.0	8.5	13.0	12.0	10.5	4.5	12.5
Total number of points	100	71.0	73.5	76.0	79.5	74.5	55.0	80.0
Average cost per square yard, laid, 1905		$3.26	$3.50	$2.36	$2.29	$2.06	$0.99	$3.10

Favorableness to travel is dependent chiefly upon smoothness and freedom from dust and mud, secondarily upon the qualities composing "Acceptability."

Acceptability includes noise, reflection of light, radiation of heat, emission of unpleasant odors, etc. It chiefly concerns the pedestrian and the adjoining resident.

Cost per square yard includes concrete, but not excavation, curbing, etc.; except for macadam, which is not usually laid on concrete.

COST.

The cost of cresoted wood pavement in the United States has varied from $2.40 to $3.50 per superficial square yard laid. As the table shows, the average cost per yard for all cities which reported was $3.10. The basis of judgment upon a pavement should be the returns upon its total cost for the life period, considered as an investment. In Europe this is done, but in the United States the first cost is in most cases given undue weight. For a pavement such as creosoted wood, the first cost of which is high, this method is very unfair and reduces the pavement's total standing much below its service value. Table 1 takes into account the factors of pavement value more systematically than do other methods used in this country, but it does not provide a basis of investment returns. A better way would be to express the cost item in terms of total annual charge; this would take into account the factor of durability, and would remove it from separate listing in the table. The result would be much more consistent and accurate.

SERVICE.

Disregarding cost, and basing the comparison upon service qualities only, the difference in favor of creosoted wood is materially increased. Wood ranks very high in every quality listed, except in freedom from slipperiness and, to a less extent, in durability. It is highest in those qualities which contribute to the acceptability of the pavement.

DURABILITY.

There is in the United States almost no wood pavement of the modern kind which has yet been down long enough to show its durability. The values assigned by the engineers to durability are, therefore, based principally on general impressions and inference from European experience. There are, however, a few cases in the United States which offer pertinent evidence.

In Baltimore, Md., in the summer of 1901, there were laid several adjacent strips of experimental pavements, including sheet asphalt, creosoted wood, and several kinds of brick. After five years' service, and after passing through the great fire, the wood was in better condition than any of the others.

In front of the Auditorium Hotel, on Michigan avenue, Chicago, is a creosoted longleaf pine pavement, laid in the year 1900. Adjoining it an area of asphalt block was laid at the same time. In 1905 the asphalt blocks were removed and replaced with wood. In the five years the asphalt had worn down on an average 1 inch, but very unevenly, so that ruts had formed and the blocks were badly rounded. The wooden blocks during this time had worn off only one-eighth of an inch, and the surface, except for a badly constructed gutter at one point, was still perfectly smooth and of even grade.

In 1902 the Metropolitan Street Railway Company, of New York City, decided to experiment with creosoted wooden blocks for paving between its tracks. A small area of longleaf pine was laid on Hudson street, the wood being flanked at either end by granite, the material hitherto used. At the point selected there is a very heavy trucking traffic from the North River wharves, and the stresses on the pavement, where the trucks run with one wheel just outside the car rail, are so great that the granite begins to show a rut in six months, and is renewed almost annually. At the end of four years the wood, though showing a heavy rut, was still sound and in position and good for at least one more year. The granite on either side had been renewed three times during the four years.

These few examples can not of course be regarded as final. There have been instances in which creosoted blocks have given poor results. But it should not be forgotten that poor preservative treatment

of the wood or faulty construction of the pavement may cause the best wood to fail. The cited cases of successful pavement indicate that such errors are responsible for the failures which have occurred, and that wood block pavement, properly prepared and laid, should be credited with a durability greater than 14 in a scale which rates asphalt blocks at 14 and whose standard is granite at 20.

Nor is this conclusion invalidated by the fact that European wood pavements, as compared with granite, show a durability relatively less than this. American longleaf pine is a harder, denser wood, and has greater resistance than the European pine used for paving. While wood preservation has in general attained a greater perfection in Europe than in America, yet American creosote treatment of wood paving blocks, discussed on page 14, is more thorough than the European.

TRACTION RESISTANCE AND FREEDOM FROM SLIPPERINESS.

These are opposing qualities, so that gain in one is likely to be made at the expense of the other. The table shows creosoted wood and the asphalts all equal in the matter of traction resistance, while on the score of freedom from slipperiness wood is placed below both of the others. This is hardly consistent. The latest experiments indicate that in these respects American sheet asphalt varies with the temperature to a greater extent than had previously been supposed. In cold weather it is exceedingly hard, smooth, and slippery; but in hot weather its softening causes it to cling to the tires and increases its traction resistance to a point greatly beyond that of wood. Of two cities, which are close together and in which the conditions affecting the pavements are practically the same, the engineer of one believes wood to be more slippery than asphalt, while the engineer of the other believes asphalt to be more slippery than wood. This is but an example of the differences of opinion which exist on this point, due in large measure to the variation in the asphalt under different conditions. In both traction resistance and slipperiness wood appears to be much more constant than sheet asphalt. In hot weather, therefore, wood is likely to be more slippery than asphalt, while in cold weather it is likely to be less slippery. Wood and asphalt are both most slippery when slightly wet. The maximum gradient recommended by the majority of engineers for either pavement is from 3 to 5 per cent, according to conditions of climate and traffic.

Between different kinds of wood there may also develop considerable differences in slipperiness. Experience in the city of Minneapolis is that Norway pine wears much less slippery than longleaf.

PROBLEMS IN WOOD PAVING.

Problems in wood paving may be grouped into two classes:

(1) Problems peculiar to wood and the wooden pavement.

(2) Problems of construction common to all pavements.

This circular deals especially with the problems of the first class. Those of the second class so closely affect the success of the whole and are so closely interwoven with the others that they can not be neglected.

THE WOOD.

One drawback in the use of wood for paving has been lack of knowledge of the wood itself. For example, sapwood has always been thought to be both weaker and more subject to decay than heartwood. It is rigidly excluded from most wood-paving specifications, and all-heart blocks demanded. The inclusion of sapwood undoubtedly caused the untreated blocks of former years to wear unevenly and to decay quickly. But the preservative treatment now applied provides against the decay. Recent tests show that under equal conditions of moisture content the sapwood of many species is as strong as the heartwood.[a] It is usually less strong because wood is rarely used under conditions where the moisture content of the sapwood is as low as that of the heartwood. Creosote treatment, with proper previous seasoning, reduces the moisture content of each to an approximately even minimum, and the heavy charge of oil now customary in American wood-paving treatment prevents subsequent absorption of moisture, beyond a small per cent. After five years' service there is no discernible difference in wear between the heart and sap portions of unseparated Norway pine blocks laid in the city of Minneapolis. In fact there is yet no measurable wear on either.

USE OF LABORATORY TESTS.

The standard mechanical and physical tests should be of service in determining the suitability of a given wood for use in pavement. But there are difficulties in the way of using them directly. Resistance to compression, indentation, and abrasion, among the mechanical properties, doubtless has a bearing upon the performance of a wood in the pavement. Yet the fact that the compression strength of longleaf pine compared with that of Norway pine is approximately as three to two does not warrant an assertion that in the pavement longleaf will outlast Norway in that proportion. Two woods of unequal strength may wear equally well as long as the ultimate resistance strength of the weaker wood continues to exceed

[a] Bulletin 70, Forest Service, U. S. Department of Agriculture, "The Effect of Moisture on the Strength and Stiffness of Wood."

the traffic strains. After five years' service in the city of Minneapolis, Norway pine appears to be wearing as well as longleaf. The action upon a pavement is so complex and is distributed over so long a time that it is difficult to correlate it with laboratory tests. The significance of these can be determined only by a careful comparison with the service results actually shown on a pavement of some of the standard woods. Yet nowhere in the United States have wooden pavements of the modern type been down long enough to warrant final conclusions.

The values on the mechanical tests of wood in the standard engineering manuals do not generally specify the moisture conditions under which the tests were made. It is only within recent years that the enormous influence of this factor upon the strength of timber has been appreciated. It is now proved, for instance, that the average compression strength of longleaf pine, parallel to the grain, when green or water soaked, is only about 30 per cent of that of the absolutely dry wood, and about 60 per cent of that of well-seasoned wood.[a] It is obvious, therefore, that tests upon different woods in which the moisture condition is not taken into account are not safe guides.

CREOSOTING.

Creosoting has generally been supposed to weaken timber. The results of recent experiments conducted by the Forest Service indicate, however, that the creosote itself does not lessen the strength of timber, but that this result in practice has been due chiefly to certain methods used in the impregnation.[b]

The Rush Street Bridge in Chicago, Ill., is said by the chief engineer of streets to carry a traffic as heavy as any in the city. It has two 20-foot roadways, which were paved in 1899, one with creosoted longleaf pine blocks, the other with uncreosoted blocks. The creosoted pavement, after a service of seven years, was still in good condition and is expected by the chief engineer to last several years more, while the uncreosoted pavement was renewed in 1902.

The explanation of these facts lies in the antiseptic qualities of the creosote and its physical action in filling the pores of the wood and decreasing its absorption of water. Every pavement is wet a large part of the time, and wood, when saturated with water, has generally less than 40 per cent of its kiln-dry strength. The creosoting treatment, by lessening the absorption of water, maintains the strength at much nearer the dry-wood value, and thereby increases the actual service strength.

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[a] Bulletin 70, Forest Service, U. S. Department of Agriculture, "The Effect of Moisture on the Strength and Stiffness of Wood."

[b] Circular No. 39, Forest Service, U. S. Department of Agriculture, "Experiments on the Strength of Treated Timbers."

This action is most effective only when the wood is well seasoned before being creosoted. In the United States most creosoters attempt to dry the wood by applying steam and vacuum. Recent experiments have shown that wood will, except when very green, weigh more after such treatment than before. That is, by this process, it will take up moisture rather than lose it. This would destroy any possible gain in strength through the creosote treatment. Not only is the steaming in most cases valueless, but if carried too far, as it often is, it seriously injures the wood.[a] Natural seasoning, which in Europe is used almost entirely, would certainly contribute to increased excellence of results in the United States.

The common opinion among engineers in regard to the creosoting of wooden pavements is expressed by a prominent paving engineer, who says, "For wood paving creosoting is only of contingent value. If the traffic is heavy enough to wear out the pavement before it decays, which it will do on most city streets, it is a waste of time and money to creosote the blocks. Creosoting is only economically desirable, therefore, when the traffic is so light that decay will reduce the block before it fails from wear." This would be true if creosoting treatment had no effect on wood pavements other than the preservation of the wood from decay. But creosoting effects, through the increased service strength of the blocks, an additional and quite different gain. It is believed that there is already enough evidence, such as that offered by the Rush Street Bridge, to overthrow the traditional doctrine of the limited value of creosote preservative treatment for wood paving.

The best preservative.—Preservative treatment for wood paving, then, must accomplish the following results:

(1) Preservation from decay.
(2) Mechanical filling of the pores, to prevent the absorption of fluids; which further accomplishes:
    (a) Elimination of expansion.
    (b) Increase of resistance to wear.
    (c) Maintenance of sanitary value.

Creosote oil seems to meet these requirements better than any other preservative commonly used. The other preservatives are mostly water solutions, which are easily leached out of the wood and thus lose their preservative effect. Moreover, being themselves largely composed of water, they do not prevent expansion in the blocks, do not increase their resistance to wear, and do not maintain them in a sanitary condition.

The same requirements which have caused creosote to supersede other preservatives in wood paving call for a larger proportion of

[a] Circular No. 39, Forest Service, U. S. Department of Agriculture, "Experiments on the Strength of Treated Timbers."

high distilling constituents in the creosote than is necessary in the preservation of timber for many other purposes.

Impregnation.—In the United States the timber for paving purposes is universally impregnated by the vacuum-pressure method. Closed cylinders, usually about 6 feet in diameter by 100 feet in length, are used. The amount of oil usually injected into the wood is 16 pounds per cubic foot, though in some cases it reaches 22 pounds. To many municipal engineers this has seemed an unnecessarily large amount, constituting an item of expense in the already high cost of wood paving which might profitably be reduced. But the necessity for the prevention of moisture absorption under conditions more exacting than those to which almost any other creosoted wood product is subjected makes imperative the impregnation of wood paving blocks with an amount of oil per cubic foot greater than that ordinarily given to railroad ties or construction timbers. The tendency is toward heavier charges rather than the reverse, to secure for wood pavement a service so greatly enhanced as to yield better returns upon the investment, even at the higher cost.

In Paris, the blocks are usually impregnated by merely soaking for a short period in an open tank, and the amount of oil injected per cubic foot is small. The life of Paris pavements so treated is from six to fourteen years only, according to the traffic; and, because of the small impregnation, expansion in the pavements is large and calls for the laying of longitudinal courses of blocks at the curbs, which are removed as it becomes necessary. The vacuum-pressure method for the treatment of wood paving blocks is only now being introduced.[a] This is the reason for the statement made on page 10 that American creosote treatment of wood paving is superior to that of Europe. The excellence of European wood pavements, despite this defect, is largely due to better construction, maintenance, and repair.

Inspection.—Our cities, which are the chief consumers of wood paving blocks, perhaps fail more than any other consumers of creosoted products to inspect properly the product and its manufacture. Cities are often dependent, even for their specifications, upon the companies which are seeking contracts. This is largely due to the technical nature of the subject, both as to processes and as to the chemical analysis of the oils, and largely also to the almost entire lack of reliable information. The Forest Service is carrying on investigations of

[a] M. Mazerolle, Ingénieur, Service Technique de la Voie, Paris, 1906.

wood preservatives and wood preservation, and results will be placed at the disposal of engineers as fast as they become available.[a]

LAYING THE PAVEMENT.

During the progress of this study the practice in wood-pavement construction was carefully observed in many cities. Some of the points are here discussed.

FOUNDATION AND CUSHION.

For the most satisfactory service, wood-block pavement requires a concrete foundation. This is usually made from 5 to 6 inches thick, although some engineers reduce it to 4 inches on lightly traveled residence streets. As a top cushion for the foundation either Portland-cement mortar or sand is used. The former is considered superior by most engineers. The bearing for the blocks is permanent, and, if carefully surface-trued, can be made as even as desired; and if the grout is mixed slightly damp and the blocks laid in it immediately, it provides equally as good a compensation for minor inequalities in the height of the blocks as sand does. If tar can be used, a better method of accomplishing the same object is to mix the grout in the usual way and let it thoroughly set, after which a coating of tar should be applied and the blocks bedded in it. This is the method oftenest used in Europe. Sand makes a satisfactory cushion where the slope is negligible and the foundation is solid. It is sometimes preferred on the ground of greater elasticity and power of accommodation, and it has the merit of being cheaper than cement. On a gradient, however, if water, by any possibility, gets under the blocks it is likely to carry the sand to the bottom of the slope and seriously derange the pavement. On bridges, also, if there is much crown on the roadway the vibration of the structure is likely to shift the sand from the center of the crown toward the gutter. For bridges the usual practice is to lay the blocks directly on carefully creosoted planking.

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[a] The following publications on this subject have been issued by the Forest Service:

Bulletin 51. Report on the Condition of Treated Timbers Laid in Texas, February, 1902.
Circular 39. Experiments on the Strength of Treated Timbers.
Circular 80. Fractional Distillation of Coal-Tar Creosote.
Circular 98. Quantity and Character of Creosote in Well-Preserved Timbers.
Circular 101. The Open-Tank Method for the Treatment of Timber.
Circular 104. Brush and Tank Pole Treatments.
Circular 111. Prolonging the Life of Mine Timbers.
Circular 117. The Preservative Treatment of Fence Posts.
Circular 128. Preservation of Piling Against Marine Wood Borers.
Circular 134. Estimation of Moisture in Creosoted Wood.
Circular 139. Primer of Wood Preservation.
Extract from the Yearbook of the Department of Agriculture, 329. Prolonging the Life of Telephone Poles.

BLOCKS.

The blocks should be rigidly inspected, especially as to imperfections of sawing, as to knot holes, decay, or defective corners or edges, as to squareness of the angles, and as to thoroughness of impregnation. Voids due to imperfections in any of these respects often can not be properly filled by the joint filler, and are very detrimental to the pavement. In European practice no variation greater than one-sixteenth inch in any dimension of the blocks, and no measurable variation in the depth, are allowed. There the blocks are also required to be kept carefully protected from sun and weather after treatment and until they are laid. Deterioration from checking, which in America is often considerable, is thus prevented.

Exclusion of second growth material from wood-paving specifications is immaterial, except in so far as young trees contain a greater proportion of sapwood than older trees; and, since sapwood is separately provided for in most cases, the specification prohibiting second-growth timber could well be abandoned. Sapwood is entirely excluded by most wood-paving specifications. Under existing market conditions, however, it is quite impossible to obtain strictly all-heart southern pine such as the specifications demand. Commercial longleaf southern pine lumber is also seldom free from an admixture of loblolly pine. The true longleaf pine has usually so narrow a sapwood that it could be neglected without danger to the life of the pavement. In loblolly the sapwood is often very wide; but loblolly pine is one of the species for which it has been proved that the sapwood under equal conditions of moisture content is as strong as the heartwood. Therefore, when effective seasoning of paving material can be assured before the creosote treatment, the prohibition of sapwood in southern pine material is needless, and should also be omitted from specifications.

A more pertinent specification would be one excluding fast-grown timber in pine paving-block stock—say all showing less than eight rings to the inch—since it is the porous wood resulting from fast growth, rather than the presence of sapwood, which unfits timber for this use.

ANGLE OF COURSES.

The angle at which the courses are laid in wood pavement is a matter of some importance. The most obvious angle is that of 90 degrees with the curb, which takes the courses straight across the street. Probably the greater part of the wood-block pavement in the United States is so laid. But this angle permits the calks of horses' shoes to strike in a direct line with the joints, and subjects the pavement to a wear and tear which may largely be avoided by laying the

courses at an oblique angle. Moreover, if expansion occurs, transverse as well as lateral expansion joints are necessary to provide against it, and transverse joints of this character in wood pavement are always undesirable. (See figure 1.) With the courses laid at an oblique angle, the thrust of the pavement in case of expansion will impinge in both directions upon the curb, and the transverse expansion joint may be entirely dispensed with.

The oblique angle which most naturally suggested itself was 45 degrees, and a large amount of pavement has been so laid. There has, however, developed an objection to this angle. Transverse expansion in wood takes place in two directions, tangentially to the rings of annual growth, and radially to them. Of these the transverse expansion is greater than the radial. As will be seen from the accompanying diagram of the common method of sawing lumber (fig. 2), a majority of blocks have their long axes in a plane tangent to the annual rings of the wood, or at least nearer to that plane than to the radial. Therefore the force due to tangential expansion will be

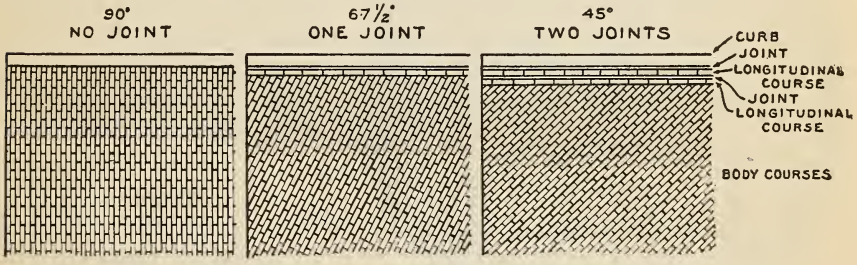

FIG. 1.—Different angles used in laying pavement.

exerted chiefly in the direction of the courses in the pavement, and the lesser or radial force will be exerted at right angles to that direction. The angle of 45 degrees does not compensate the differential expansions in the wood, and in uncreosoted or poorly creosoted pavements twisting strains have developed.

The angle between 45 and 90 degrees from the curb has therefore been bisected by some engineers, making the angle with the curb consequently 67½ degrees. This solution of the problem was an entirely empirical one, but it seems to avoid the difficulties experienced with the previous angle.

JOINTS.

On this point little need be said, except in the matter of expansion joints. The superiority of the tight body joint is unanimously admitted by those who have had experience with wood pavement. Transverse expansion joints are without doubt altogether bad. The

objection is the same as that against wide body joints, that the filler wears away faster than the blocks, leaving a depression which permits the edges of the blocks to wear off and destroys the smoothness of the pavement. Expansion joints should be longitudinal at the curb, with a longitudinal course of blocks between the expansion joint and the body of the pavement, and between each expansion joint if more than one is used. (See figure 1, page 17.) The most satisfactory results have been obtained by leaving the expansion joint open for a few days, when it may be filled with sand or, if pitch is used to fill the body joints, with sand up to within one-half inch of the surface and the remainder with pitch.

Considerable creosoted block pavement in the United States has been laid without any expansion joints, and where the creosoting of the blocks, as well as the laying of the pavement, has been well done, little serious trouble has been experienced; but it is safer to provide expansion joints.

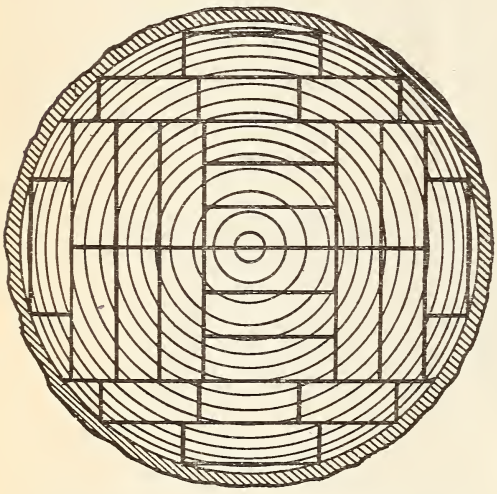

FIG. 2.—Method of cutting planks from logs.

FILLER.

There is some uncertainty among engineers as to the best joint filler for creosoted wood pavement, and several cities are experimenting. A prominent engineer gives it as his opinion that if the traffic is heavy, so that the joints between the blocks will be speedily obliterated, a sand joint may be used as well as any other, and it is considerably cheaper than the others. But if the traffic is not heavy enough to obliterate the joints, sand permits the ingress of water, and gradually works down and leaves a space to be filled with débris, which lowers the sanitary value of the pavement. Cement mortar as a filler is waterproof at first, but it soon crumbles and becomes then no better than sand. Besides it is too inelastic and increases the noise from the pavement.

Except under heavy traffic, therefore, some substance like coal-tar pitch is preferable. But pitch has this disadvantage—that a grade which will not crack under the cold of winter is likely to become soft

and sticky in the heat of summer. Care is necessary to select a quality which shall avoid these difficulties. There are now some proprietary preparations on the market which offer specific advantages as fillers, since their range of stability is greater than that of pitch, so that they become neither brittle nor sticky, at least under natural conditions in a temperate climate. To fill the joints effectively, pitch should be heated to about 300° F. when applied, so as to insure perfect fluidity.

TOP DRESSING.

The top dressing for wood pavement is usually of screened, sharp sand or of finely crushed stone, about one-half inch in thickness. This is allowed to remain on the pavement about two weeks, or longer when convenient. The top dressing benefits wood pavement in several ways. A certain amount is ground into the surface of the blocks and both increases their resistance to abrasion and reduces slipperiness. If sand has been used for a joint filler the surface sand keeps the joints filled as they settle, and if the joint filler is pitch the sand takes up any surplus pitch from the surface of the blocks and leaves the pavement cleaner than it would be without it. A subsequent occasional light sanding is a distinct advantage to the pavement; but this is a matter of maintenance.

MAINTENANCE.

In the care of the pavement after it is laid American cities fail more seriously, perhaps, than in any other particular. Once laid, the pavement is often expected to take care of itself without any further attention. This is often due to causes beyond the control of the engineer; but the fact remains that such treatment may go far to defeat the best manufacture and construction. In Europe wood pavements are cleaned with regularity and care. They are frequently flushed with water and are never allowed to dry out, as they often do to an excessive degree in the summer droughts in America. They are sanded at regular periods, as well as on any occasions of special slipperiness. Most American cities appear to consider that such maintenance as is given in Europe is impossible here. A few, however, do give adequate care to their pavements, and it is believed that for many others greater attention in this direction would be a paying investment rather than an expense.

THE EXPERIMENTAL PAVEMENT.

To learn the results of actual service on a larger number of woods than the manufacturers seemed likely to try under the existing

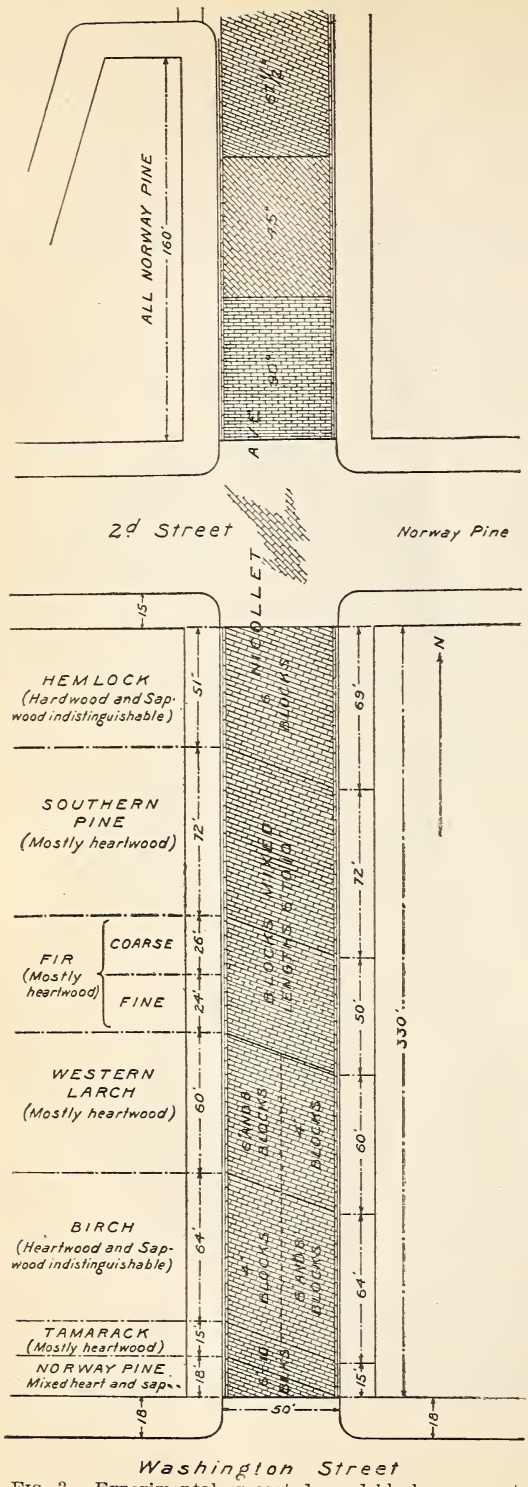

Fig. 3.—Experimental creosoted wood block pavement.

public prejudice against unproved woods, the Forest Service undertook arrangements for the laying of an experimental pavement, in which some of the untried woods should be laid with those already standard. This experiment was carried out in cooperation with the city of Minneapolis, Minn., and with the Republic Creosoting Company and the Kettle River Quarries Company, both of Minneapolis.

Having initiated the experiment, the Forest Service worked out its organization, secured the contribution of the lumber, and was responsible for the general conduct of the undertaking. The woods used were donated to the Forest Service by various lumber firms and lumbermen's associations, which were interested in extending the markets for their respective products. The creosote oil and the manufacture and treatment of the blocks were contributed by the two creosoting companies cooperating in the experiment. The area to be paved was selected and the pavement was laid by the city of Minneapolis.

VARIABLES.

The variables in this experiment, by means of which it was desired to gain information upon the points respectively involved, were:

(1) Species of wood.
(2) Heartwood and sapwood.
(3) Length of blocks.
(4) Angle of courses.

SPECIES OF WOOD.

The woods used in the experiment were longleaf pine, Norway pine, tamarack, Douglas fir, Western larch, white birch, and hemlock. The longleaf pine was included in order to provide a standard of comparison by which the behavior of the other woods could be judged, since it is the species most used in the United States. It was the purpose to lay equal amounts, approximately 15,000 feet board measure, of each wood, or, allowing for ordinary waste in manufacture, about 65 linear feet of pavement on a street 50 feet wide. Various circumstances, particularly a lack of knowledge on the part of some of the lumber companies of the peculiar requirements for paving stock, largely increased the waste in sawing the blocks, and prevented the full area being laid with some of the woods. The shortage in these woods was made up by others of which larger amounts were obtainable. The distribution of the species, as laid, is shown in figure 3.

HEARTWOOD V. SAPWOOD.

The character of the blocks of the different woods used was as follows:

Approximately all heart: Longleaf pine, Douglas fir, and Western larch.
Mixed heart and sap: Norway pine and tamarack.
Heartwood and sapwood indistinguishable: White birch and hemlock.

It was unnecessary to make separate classes for this condition within the separate species, since any difference in resistance between heartwood and sapwood would become manifest in an uneven wearing of the blocks, rather than in a greater total wear. Therefore this variable would not obscure the results affecting the separate species.

LENGTH OF BLOCKS.

The lengths of the blocks in the different species are as follows:

	Inches.
Longleaf pine, variable	6 to 10
Norway pine_____do	6 to 10
Tamarack _____do	6 to 10

	Inches.
Douglas fir, variable	6 to 10
Hemlock	6
Western larch (one-half)	4
Western larch (one-half)	6 and 8
White birch (one-half)	4
White birch (one-half)	6 and 8

The width, and also the depth, of all the blocks was 4 inches. The larch, birch, and hemlock were air-seasoned for several months before being used. Exact records of the time of seasoning of the other woods were not obtainable, but none of them were entirely green when used. Of the Douglas fir a portion was from very rapidly grown stock, and it was feared that it would be so weak that it would not fairly represent the average of this timber. Therefore further separation on the basis of this factor was made for this wood, and the narrow-ringed and wide-ringed blocks were laid in separate portions of the pavement.

CREOSOTING THE BLOCKS.

It was not attempted in this experiment to make any variables in connection with the treating process. The blocks were treated at the plants of the two creosoting companies cooperating in the experiment, with a straight creosote treatment under the current specifications of the city of Minneapolis governing all creosoted paving material then supplied to that city. The work was supervised by an inspector for the city, and by a representative of the Forest Service.

The specifications of the city of Minneapolis require an impregnation of 16 pounds per cubic foot, with creosote oil, as follows:

> The specific gravity of the oil, at 20° C., shall be at least 1.09.
>
> The oil shall be completely liquid at 25° C., and show no deposit on cooling to 22° C.
>
> It shall not contain more than 2 per cent of water nor more than 3 per cent of matter insoluble in absolute alcohol or benzene.
>
> Distillation test: One hundred grams of oil shall be placed in an 8-ounce retort, fitted with a thermometer the bottom of whose bulb shall be placed one-half inch above the oil and not moved during the test. The discharge opening of the retort shall be from 20 to 24 inches from the bulb of the thermometer, and the retort shall be covered to prevent too rapid radiation. The percentages are for dry oil, and by weight:
>
> Up to 150° C., nothing must come off.
>
> Up to 170° C., 2 per cent.
>
> Up to 210° C., from 6 per cent to 8 per cent.
>
> Up to 235° C., from 20 per cent to 30 per cent.
>
> Up to 315° C., from 40 per cent to 50 per cent.
>
> Up to 355° C., from 60 per cent to 80 per cent.
>
> Distillation shall be gradual, and be completed, up to 315° C., in thirty minutes from the first drop, and entirely completed in forty minutes.

This specification calls for an oil considerably heavier than the average in use. The oil used by the Republic Creosoting Company came up to the specifications. At the time when it became necessary to do the creosoting the Kettle River Quarries Company was not able to supply a creosote which complied with the specifications, that which it had being lighter, and containing about 40 per cent of the naphthalene fraction, with correspondingly less of the higher distillates. To compensate as far as might be possible for this lack of conformity to the city requirements, the Kettle River Quarries Company increased the impregnation to about 20 pounds per cubic foot. The timbers thus treated were western larch and white birch.

CONSTRUCTION OF THE PAVEMENT.

Nicollet avenue, on which this pavement is laid, is 50 feet wide. There is practically no gradient. The street was so prepared as to give to the pavement a crown of 8 inches. The foundation was made of Portland cement concrete, composed of Portland cement 1 part, sand 3 parts, crushed limestone 7 parts; and was 5 inches in thickness. Over this, as soon as it was sufficiently set, was spread a 1-inch cushion of sand. The surface of the sand was carefully trued to grade, and upon this foundation the blocks were laid, as shown in figure 3.

The area of the avenue between Washington street and Second street was reserved for the several species to be compared, and these were laid all at the same angle, 67½ degrees with the curb. North of Second street one wood, Norway pine, only, was laid, and on this area different angles were used for the courses, one portion being laid at 90 degrees to the curb, another at 45 degrees, and a third at 67½ degrees. The relation of these areas will be seen from the figure.

The body of the pavement was laid with close joints, the pavement being driven moderately after every dozen or so courses. At each curb was left a 1-inch expansion joint, between which and the body of the pavement was one longitudinal course of blocks. As soon as the pavement was laid it was thoroughly rolled with a steam roller. The expansion joints, which had been left open until the pavement should be rolled and thoroughly settled, were then filled with sand nearly to the top. The body joints and the top of the expansion joints were filled with pitch, heated to about 300° F., which was thoroughly broomed in with steel brooms. A light top dressing of sharp sand completed the pavement. As soon as thorough setting of the concrete was assured traffic was admitted.

Traffic records will be taken for this pavement by the city of Minneapolis at regular intervals, so arranged as to give a knowledge

of the average traffic throughout the year in terms of tons weight per yard width of the pavement per day, and the pavement will be under careful inspection in all particulars. Final results will not be obtainable for several years, though many useful facts may be demonstrated before that time. It is hoped that the experiment may throw light upon the problems to which it has been addressed, and may assist in bringing about the introduction in creosoted wooden block pavements of other suitable and available woods to supplement those now in use. Since the study was made, the introduction of some other woods has already been begun in several cities.

Approved:

JAMES WILSON,

Secretary of Agriculture.

WASHINGTON, D. C., *December 14, 1907.*

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